

Comments on arXiv:1006.0972 “XENON10/100 dark matter constraints in comparison with CoGeNT and DAMA: examining the \mathcal{L}_{eff} dependence”

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Savage *et al.* [1] have recently put forward the claim that results from the XENON10 experiment are incompatible with the totality of both DAMA/LIBRA [2] and CoGeNT [3] experimental regions. In this brief note the source of this erroneous conclusion is identified in a misinterpretation of the XENON10 efficiency in the detection of $S1$ light from low-energy nuclear recoils.

I intend to keep this discussion factual and brief and refer an interested reader to the literature cited: the main thesis in [1] is that XENON10 provides more astringent light-mass WIMP limits than XENON100, by virtue of its lower energy threshold (2 $S1$ photoelectrons (PE) or ~ 4.6 keV_r, as opposed to 4 $S1$ PE or ~ 9.5 keV_r). Unfortunately, from comments made in [1], it is clear that the authors have neglected to include in their analysis the effect of the XENON10 efficiency in extracting a larger than two-fold $S1$ PE coincidence, one of the requirements for acceptance of an event in both XENON10 and XENON100.

This efficiency is assumed by Savage *et al.* to be a flat 100% down to zero recoil energy in XENON10. In reality it is a rapidly decreasing function below ~ 10 keV_r, becoming zero somewhere in the region 1 keV_r to 3.5 keV_r¹. The importance of this $S1$ detection efficiency is mentioned in a recent release from XENON100 [4] (by remarking that it is a relatively minor issue when dealing with a 4 $S1$ PE or ~ 9.5 keV_r threshold in that detector), is covered in technical detail for XENON10 in [5], and has been recently emphasized in [6]. By adopting the same erroneous efficiency it is possible to obtain results (dotted green lines in top Fig. 1) essentially indistinguishable from those derived by Savage *et al.* Once the correct efficiency is included, limits are extracted that are much more relaxed (rest of the lines in top Fig. 1), showing compatibility with both DAMA/LIBRA and CoGeNT, in particular when the additional sources of uncertainty discussed below are included. For clarity, only the lower 1 σ C.L. boundary (dashed green line) for the most conservative \mathcal{L}_{eff} extrapolation attempted by Savage *et al.* is included in Fig. 1. The solid green lines correspond to the dotted green lines when the correct $S1$ efficiency is applied.

While mistakes can be made and will be made, a limited treatment of the uncertainties affecting these experiments is also evident in [1]. This is in contrast with the more balanced position that some of us have at-

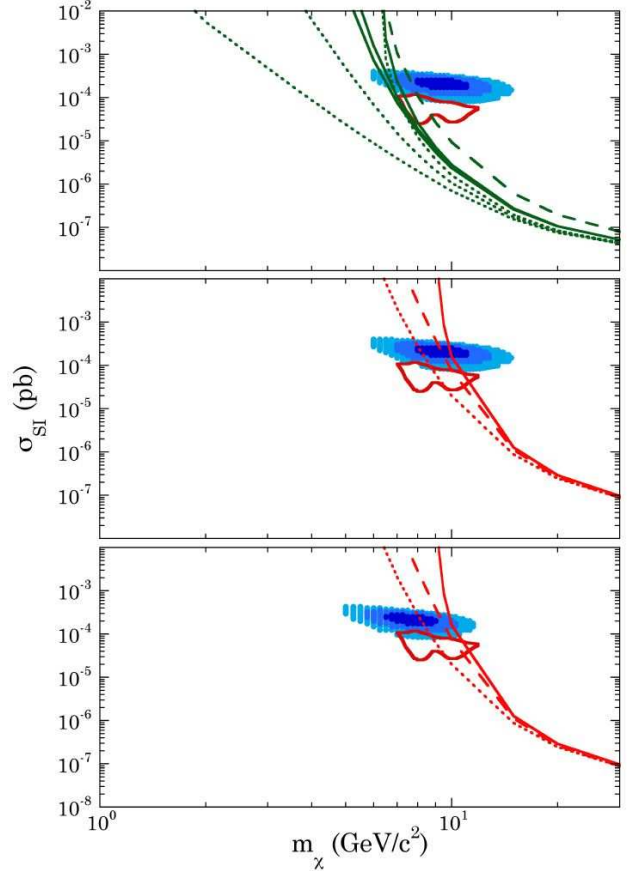


FIG. 1: XENON10 exclusion limits obtained under a variety of assumptions, some erroneous, some not (see text). For consistency we use here our own derived DAMA/LIBRA and CoGeNT regions (1 σ , 2 σ , 3 σ and approximate 90% C.L. respectively), employing the same astrophysical parameters as in [1, 12].

tempted to take in [7]. It is claimed in [1] that the most conservative XENON constraints can be obtained by attempting different low-energy extrapolations of the scintillation efficiency function \mathcal{L}_{eff} derived by Manzur *et al.* [8]. While \mathcal{L}_{eff} for liquid xenon (LXe) should in principle be a detector-independent quantity (unfortunately far from experimental reality as of today), the detector-specific $S1$ detection efficiency mentioned above plays a role in its derivation [5, 6]. It would then seem natural to examine the sensitivity that can be obtained from XENON10 data by using the latest \mathcal{L}_{eff} that can be derived from that very same experiment [6]. This is rep-

[1] Here a cutoff value of 2 keV_r corresponding to the Manzur *et al.* \mathcal{L}_{eff} model is adopted for consistency.

resented in Fig. 1 (middle panel) by a dotted red line. Sub-threshold Poisson fluctuations are conservatively assumed in all these calculations, as well as an allowance for a non-zero \mathcal{L}_{eff} all the way down to zero recoil energy. For the case of XENON10, this is done via an adiabatic fit as in [9], which yields good agreement with the expected kinematic cutoff for LXe [7]. This assumption of finite response down to zero recoil energy is another conservative premise that we have emphasized does not have to be warranted in reality, and one that dominates the sensitivity extracted for these low-mass WIMPs [7]. Other values of \mathcal{L}_{eff} neglected by Savage *et al.*, such as that recently measured by the ZEPLIN collaboration [10], provide even more conservative limits (red dashed lines) under similar generous premises. It is observed that both \mathcal{L}_{eff} functions derived from ZEPLIN and most recently for XENON10 are compatible within uncertainties with a zero value for \mathcal{L}_{eff} below $\sim 8 \text{ keV}_r$ once the $S1$ threshold bias is included for the second [6]. We also examine this most moderate possibility, obtaining limits (solid red lines) not very different from those that can be generated in the absence of Poisson fluctuations [6].

The bottom panel in Fig. 1 is offered as an illustration of the many additional uncertainties affecting dark matter experiments in this low-mass WIMP region, a subject already brought up in [7]. The position of the

DAMA/LIBRA favored region is arguably particularly sensitive to these, since its derivation includes additional halo model uncertainties via the magnitude of the annual modulation. Here a simple minor alteration to the quenching factors for NaI[Tl] is made, in going from the usual $Q_{Na}=0.3$, $Q_I=0.09$ applied in the top and middle panels, to a $Q_{Na}=0.4$, $Q_I=0.05$ as derived in [11]. Just this small modification is enough to considerably relax any tension with XENON10 constraints. Such additional uncertainties will be treated in an upcoming publication.

In conclusion, it is found that the main thesis in Savage *et al.*, namely that XENON10 “is incompatible with the DAMA/LIBRA 3σ region and the 7-12 GeV WIMP mass region of interest in CoGeNT” is the result of a mistake in their understanding the XENON10 efficiencies, together with an additional incomplete treatment of present-day uncertainties. No attempt has been made here to cross-check any of the findings made by Savage *et al.* in respect to the other experiments they mention. An interested reader is referred to [7] for a careful treatment of XENON100. The intricacies of the experimental details and abundant uncertainties affecting the low-mass WIMP region, specially in the case of LXe, do not invite any rushed conclusions.

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- [1] C. Savage *et al.*, [arXiv:1006.0972](#).
 - [2] R. Bernabei *et al.* (DAMA collaboration), *Eur. Phys. J.* **C56** (2008) 333.
 - [3] C.E. Aalseth *et al.* (CoGeNT collaboration), submitted to *Phys. Rev. Lett.*, [arXiv:1002.4703](#).
 - [4] E. Aprile *et al.* (XENON100 collaboration), [arXiv:1005.0380v1](#).
 - [5] P. Sorensen *et al.* (XENON10 collaboration), *Nucl. Instr. Meth.* **A601** (2009) 339, [arXiv:0807.0459](#).
 - [6] P. Sorensen *et al.* (XENON10 collaboration), in preparation; P. Sorensen, presented at the 2010 Light Dark matter Workshop, UC Davis, available from <http://particle.physics.ucdavis.edu/seminars/data/media/2010/apr/sorensen.pdf>
 - [7] J.I. Collar and D.N. McKinsey, [arXiv:1005.0838](#) and [arXiv:1005.3723](#).
 - [8] A. Manzur *et al.*, *Phys. Rev.* **C81** (2010) 025808, [arXiv:0909.1063](#).
 - [9] D.J. Ficenec *et al.*, *Phys. Rev.* **D36** (1987) R311; S.P. Ahlen *et al.*, *Phys. Rev.* **D27** (1983) 688.
 - [10] V.N. Lebedenko *et al.* (ZEPLIN collaboration), *Phys. Rev.* **D80** (2009) 052010, [arXiv:0812.1150](#).
 - [11] K. Fushimi *et al.*, *Phys. Rev.*, **C47** (1993) R425.
 - [12] J.D. Lewin and P.F. Smith, *Astropart. Phys.* **6** (1996) 87.